PB90-134263

Future Challenges for Air Pollution and Forest Ecosystem Research in the West

(U.S.) Corvallis Environmental Research Lab., OR

1989

U.S. Department of Commerce
National Technical Information Service
NTIS

ERL-COR- 1026D

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before comp'

1. REPORT NO. EPA/600/D-89/219	2. PB90-134263
4. TITLE AND SUBTITLE: Future Challenges for Air Pollution and Forest Ecosystem Research in the West	5. REPORT DATE
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): A. Ross Kiester	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: NSI,US EPA, ERL-Corvallis	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS: US Environmental Protection Agency Environmental Research Laboratory 200 SW 35th Street Corvallis, OR 97333	13. TYPE OF REPORT AND PERIOD COVERED: Symposium Paper
	14. SPONSORING AGENCY CODE: EPA/600/2

15. SUPPLEMENTARY NOTES
In Proceedings Effect of Air Pollution on Western Forests APCA annual meeting, June 1989 in Anaheim, CA.

16. ABSTRACT

The air quality and biological diversity of the western United States pose special problems for future research. For those who desire generality this diversity provides a challenge to find general patterns that cover the West. For those, such as regulators, who need information on particular sites, the West provides an overwhelming number of potential special cases. Thus the West also exemplifies the problem of the relationship between two kinds of scientific activity: the search for generality and the determination of particulars. Here I propose that future studies should include many more comparative analyses to address this problem. In this view the diversity of the West becomes a major scientific resource.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT: Release to Public	19. SECURITY CLASS (This Report): Unclassified	21. NO. OF PAGES: 10
	20. SECURITY CLASS (This page): Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

EPA/600/D-89/219

Future Challenges for Air Pollution and Forest Ecosystem Research in the West

A. Ross Kiester
Project Leader
Synthesis and Integration Project
Forest Response Program
EPA Environmental Research Laboratory
Corvallis, OR 97333

ABSTRACT. The air quality and biological diversity of the western United States pose special problems for future research. For those who desire generality this diversity provides a challenge to find general patterns that cover the West. For those, such as regulators, who need information on particular sites, the West provides an overwhelming number of potential special cases. Thus the West also exemplifies the problem of the relationship between two kinds of scientific activity: the search for generality and the determination of particulars. Here I propose that future studies should include many more comparative analyses to address this problem. In this view the diversity of the West becomes a major scientific resource.

1 INTRODUCTION

In this essay I want to show how the diversity of the West casts into relief the problem of the relationship between the general and the particular in the study of the effects of air pollution on forest ecosystems. Below I will first describe something of the diversity of the West as it relates to air pollution and forestry research. I will then describe a dilemma that ecologists face: the desire for generality and the need for particulars. Finally I will argue that an emphasis on comparative studies on all levels of biological organization in future research will help eliminate this dilemma.

2 DIVERSITY IN THE WEST

I begin by simply recalling the diversity of the West in four areas: landform, climate, air quality, and biological diversity are all higher here than in other parts of the country.

2.1 Landform Diversity

The western United States is highly diverse with regard to landforms. Browsing through any atlas, Muir[1] or DeVoto[2] pleasantly establishes this point. The range in altitude in many different mountain systems is perhaps the most fundamental aspect of landform diversity as it affects climate, air quality and biological diversity. The highest point in the continental United States (Mt. Whitney at 14,494 ft.) and the lowest (Death Valley at -282 ft.) are within sight of each other on the proverbial clear day.

2.2 Climatic Diversity

Climatic diversity of the West follows from the topographic diversity coupled with the influence of the Pacific Ocean. Sprague[3] remarks: "Climatic factors have an unusually wide range in California, largely owing to the influence of mountains. There are several different climates, and marked differences in climatic conditions occur within short distances because of the local topography." Regionalization of climate can be accomplished[4], but many regions are created.

2.3 Air Quality Diversity

Because much of the West is sparsely settled while other parts are very densely settled, and because of topography and climate, air quality is also highly variable in the West. Some of the cleanest sites and some of the worst sites in the world occur here. Bohm[5] has reviewed the west-wide patterns of air pollution as they coincide with forested ecosystems and finds that the diversity of air quality at forest sites is very high.

2.4 Biological Diversity

It should also not be necessary to belabor the incredible biological diversity of the West. As an example, though, consider the flora for just Southern California[6]: It is 1,086 pages of fairly fine print. The flora for all of California[7] is 1,681 pages. Much of this diversity is contained within forest ecosystems.

3 THE GENERAL AND THE PARTICULAR

Richard Levins[8] has said that in ecology the general does not contain the particular. Or put perhaps more specifically, too close an examination of the predictions of a general theory may be like looking at a map with a microscope. Ecologists react to this observation in various ways. Some believe, as with Levins, that it is the generality that is scientifically interesting. This is the usual desire of those engaged in the scientific enterprise to search for generality. Others emphasize the need for careful studies of individual cases as a response to this realization. At an extreme they may view ecology as the sum of a set of special cases. As with the rest of ecology, in the study of the effects of air pollution on forest ecosystems one sometimes deals with the general and sometimes the particular. The complexity of the relationship between the general and the particular poses a genuine problem for this type of research. In this section I will sketch some aspects of this problem.

3.1 The Desire for Generality

3.1.1 Kant's Argument: The Need for Theory and Judgement

To begin with we must recognize the absolute need for theory *and* the fact that the application of theory must ultimately require judgement. In 1793 Kant[9] stated this forcefully:

> However complete the theory may be, it is obvious that between theory and practice there must be a link, a connection and transition from one to the other. To the intellectual concept that contains the rule, an act of judgment must be added whereby the practitioner distinguishes whether or not something is an instance of the rule. And since we cannot always lay down rules for our judgment to observe in subsumption (as this would go on ad infinitum), there may be theoreticians who, for lack of judgment, can never be practical: physicians or jurists, for example, who have been well schooled but do not know what to do when they are summoned to a consultation.
>
> But even where we find this natural gift, there may be a lack of premises. The theory may be incomplete, perhaps to be supplemented only by additional experiments and experiences from which the trained physician, agriculturist, or economist can and should abstract new rules of his own, to complete the

> theory. Thus, when the theory did not work too well in practice, the fault lay, not in the theory, but rather in there being *not enough theory* ....

These claims are backed by an argument that the development of knowledge and the development of the application of knowledge proceed best when guided by a theory, even if incomplete or incorrect. Or as Bacon says: "Truth arises more readily from error than confusion."

3.1.2 Varieties of Generality

In the study of air pollution and forest ecology a number of different kinds of generality may be sought. All of them pose the problem of their relation to the particular except the first.

3.1.2.1 Generality as commonality

Commonality is a form of generality where those properties that are in common with all systems are sought. Biochemical examples are the most common. For example, almost all species use the same form of cytochrome-c. This is a general statement and it applies to almost all particular cases. The problem is that for most effects of pollution on ecological systems, the things that the systems have in common do not have very much bearing on how the system will respond to pollution. If this kind of generality really worked we could do all of our research on *Chlorella*.

3.1.2.2 Generality as abstraction

This is what is perhaps most commonly meant by generality. It is also the most difficult to achieve. Abstract properties of trees or ecosystems are our most valuable tools for understanding trees and forests, but they are also the most difficult to apply specifically.

3.1.2.3 Generality as statistical functions

Statistical functions are a special kind of abstraction. They seem straightforward, but even for something as simple as a mean there may be in any population enough outliers to make particular use of the mean dangerous. More importantly in analysis of ecological systems the choice of the statistical functions to best describe the processes that a population is undergoing may not be obvious. For example, is the mean or the variance more important in describing the behavior of trees in a variable environment? To answer this question requires viewing statistical functions as very abstract entities.

3.1.2.4 Generality as regionalization

Regionalization is commonly practiced in this area of research on topics such as climate[4] or ecoregions[10]. Regionalization as generalization has much in common with statistical functions and suffers the same problems. Alternative regionalizations are difficult to adjudicate in the absence of any mechanistic theory of regions.

3.2 The Need for Particulars

If we have established the desire for generality, we can now attempt to understand why generality alone is not enough to solve problems. The need for particulars is especially important in the area of air pollution research on forests.

3.2.1 Trow's Argument: Everywhere and Nowhere versus Somewhere

G.W.S. Trow[11] in a wonderful essay contrasts the different styles of basic science (say, botany or ecology) with the science of silviculture. He quotes Gifford Pinchot: "Of the silvicultural character of American trees we are almost equally [compared to foreign species] ignorant." The quote is from 1893 and Trow continues:

> This is a true statement to this day and it is clear why: it is hard to get to know the silvicultural character of trees (there are countless elements that affect the growth of trees in situ over their long life), and, given the way we prefer to live in America, there is no very good reason for trying. ... We know about trees what we think we need to know, and what is *exciting to know*. That is, we know what men at work in basic science tell us is true for *very many trees* or *all trees*; we know from experience which species, growing under what conditions, harvested in which way, fit best into the framework of our economic life as it exists now. Nearly all else is still hidden.
>
> *Everywhere and nowhere* is the way of national life and is also the place where *basic scientific research* is to be found. It may be of interest to some few persons that the first work was done is this or that place, but the success of the work is in proportion to the degree to which the work is diffused throughout the world.
>
> Mostly here is the way of silviculture, and also of human settlements, which must necessarily be affected by specific local conditions.

Trow says that in our present society "... when an event is merely *somewhere* it has failed." Because of this belief, sciences like silviculture are accorded little or no status and we are unable to discover ways to make the forest healthy. And general science cannot provide answers to the detailed questions needed for silviculture and air pollution control which is a science that must exist *somewhere* as well.

3.2.2 Equity

It is perhaps worth noting that in the law, which is an important aspect of air pollution control, the general also does not contain the particular: "General considerations do not decide concrete cases" said Oliver Wendell Holmes. The myriad of details that affect any one case and distinguish it from the general rules of law are called equity[12] and the law accords them a critical role in all cases.

3.2.3 Casuistry

There is a similar concept in the theory of ethics. Casuistry is the determination of particular ethical actions from general ethical principles. Casuistry is often taken to be a pejorative term and the process is widely believed not to work[13].

3.3 The Dilemma

So the dilemma is this: Most scientists in our society strive to produce general results. Some sciences such as silviculture and air pollution effects on forests need particular information, that is information that

may be entirely specific to a particular place and time. The diversity of the West exacerbates this dilemma by providing such a wealth of particular special cases.

The question now is: Can this dilemma be eliminated by application of effort or is it symptomatic of a deeper problem? One might argue that the two groups of ecologists could go their own ways and that the only thing keeping us from doing all of the special cases in the West is a lack of effort or resources to get the job done. This is, perhaps, Trow's claim: The dilemma is a societal problem. On the other hand, Kant's claims can be taken to indicate that the dilemma has an important conceptual basis as well. I think that a resolution to the dilemma lies in the use of judgment. Kant emphasizes its coequal role with theory and Trow argues that the root of the problem he describes lies in our society's growing lack of faith in the judgment of its individuals. We need both theory and people willing to use *and* accept judgment. But how do we do this in the face our society's apparent unwillingness to accept judgment? I believe the solution is to develop a method so the relation between the direct application of theory and the use of judgment is made clear. Comparative science may provide some of the needed clarity by emphasizing the similarities *and* differences between the members of any set of ecological entities.

4 COMPARATIVE SCIENCE

In biology comparative science can be very powerful and work at any level of organization from comparative biochemistry to comparative ecosystem studies. The comparative approach is most often associated with evolutionary biology, but need not be so. Comparisons can also be made across a variety of research methodologies.

4.1 Comparisons Across Biological Levels of Organization

In designing research on the effects of air pollution on forests it is often helpful to consider the hierarchy of biological levels of organization as a conceptual tool for organizing diverse kinds of information. Schroeder and Kiester[14] describe one such approach used by the Forest Response Program, the component of the National Acid Precipitation Assessment Program designed to determine the effects of acid deposition on trees and forests. An important step beyond using the hierarchical approach is to make comparisons between systems at each level. So studies of the effect of certain pollutants on specific biochemical pathways need to be done for many species and conditions up to comparisons of regional responses for different regions.

4.2 Comparisons Across Methods

Diamond[15] has emphasized the plurality of methods that may be used in empirical ecological studies: from laboratory experiments to field experiments to what he calls natural experiments. Again comparisons can be made across any of these methods.

4.3 How Comparisons Help

In order to compare the members of a set of ecological entities, a scientist must judge which properties of the individuals are being allowed to vary and which are to be included under the invocation of the assumption of *ceteris paribus* ("all other things being equal"). This is similar to the design of an experiment in which certain factors are allowed to vary and

others are controlled. The difference is that in an experiment all non-varying factors are assumed to be controlled by the design of the experiment while in a comparison the non-varying factors are assumed to be the same. A crucial task, then, in designing a comparison is that all important non-varying factors be listed. This listing involves two judgments: first that a factor is important and second that it is legitimate to include it in the *ceteris paribus* assumption. The degree to which these judgments are clear is the degree to which the list is constructed and motivated. For example, in a comparison of tree biochemical responses to pollution across species, soil water availability may be taken to be important and placed in the list of *ceteris paribus* assumptions. In other words, to make the desired comparison we assume that soil water availability is one of the things that is among the everything else being assumed equal. We might also judge that variations in the gravitational field are not important and therefore not place that factor on the list of properties we *have* to assume are otherwise equal.

If we believe that comparisons are a useful way to proceed, then we can easily see the special opportunity provided by the West. With its range of diversity, nature in the West has given us the raw material for many comparisons and we can treat these as natural experiments and as ways to clearly delineate the judgments we make in applying theory to the many particular cases in the West.

4.4 An Example: Genetic Control of Tree Response to Pollution

Much genetically controlled variability exists in the response shown by trees to pollution[16]. This variability is typical of the response of plants to any environmental factor. Botanists often use what are called reciprocal gardening experiments to study the relation between genetic variability and environmental response. Clausen, Keck and Hiesey[17] in a classic study grew yarrow (*Achillea*) from different altitudes in the Sierra Nevada at those different altitudes. These comparative experiments showed that local genetic adaptation, the environment in which the plant was raised *and* the interaction between the two were all important. This is an important general result.

In forestry similar experiments are often undertaken. These experiments are known as provenance trials[18]. The purpose here is to determine which genotype grows best in a particular location so that a silvicultural decision can be made. These are important particular results.

The point here is that a carefully designed comparative experiment can provide results that are useful for both general and particular insights. Given positive results of a reciprocal gardening experiment along a gradient of pollution, we could then begin to list the factors that were assumed important but not held constant. The nature of this list then will specify the uncertainty surrounding any general interpretations. And the results of the individual experiments (the actual raw data) will provide particular silvicultural insights.

5 CONCLUSIONS

Two of the many challenges facing us in the future of research on air pollution effects on forested ecosystems in the West must be: 1) the description of the diversity and variation in the West whether of a biochemical or ecosystem nature and whether apprehended through laboratory experiments or field observations, and 2) the organization of that variability through comparative analyses at all levels of biological organization and for all methodologies. This

program should help to make clear the nature of judgments that we must make in the application of the general to the particular and perhaps restore some confidence in the role of judgment. I believe that these trends are already underway as can be seen in discussions on the inappropriateness of simple measures of pollution effect on ecosystems which are in place only because they can be applied without the exercise of judgment[19].

Finally, I would like to emphasize that the relation between the nature of the science we do and the environmental ethics and policy that we have is a complex one that continues to evolve and become more sophisticated[20].

6 LITERATURE CITED

1. J. Muir. The Mountains of California. The Century Company: New York. pp. 1-381 (1894).
2. B.A. DeVoto. Across the Wide Missouri. Houghton Mifflin Company: Boston. pp. 1-483 (1947).
3. M. Sprague. "Climate of California." United States Department of Agriculture Yearbook 1941: 783-797 (1941).
4. V.L. Mitchell. "The regionalization of climate in the western United States." Journal of Applied Meteorology 15: 920-927 (1976).
5. M. Bohm. "Regional characterization of air quality in the coniferous forests of the western United States." Proceedings of the 82nd Annual Meeting of AWMA, Anaheim, California, June 26-30 (1989).
6. P.A. Munz. A Flora of Southern California. University of California Press: Berkeley. pp. 1-1086 (1974).
7. P.A. Munz, D.D. Keck. A California Flora. University of California Press: Berkeley. pp. 1-1681 (1965).
8. R. Levins. Evolution in Changing Environments. Princeton University Press: Princeton, NJ. pp. ix+120 (1968).
9. I. Kant. On the old saw: That may be right in theory but it won't work in practice. University of Pennsylvania Press: Philadelphia. pp. 1-81 (1974 reprint of 1793).
10. J. M. Omernik. "Ecoregions of the conterminous United States." Annals of the Association of American Geographers 77:118-125 (1987).
11. G.W.S. Trow. "The Harvard Black Rock Forest." New Yorker pp. 44-99. June 11, (1984).
12. I.F. Stone. The Trial of Socrates. Little, Brown and Company: Boston, MA. (1988).
13. B. Williams. Ethics and the Limits of Philosophy. Harvard University Press: Cambridge (1985).
14. P. Schroeder, A.R. Kiester. "The Forest Response Program: National research on forest decline and air pollution." Journal of Forestry 87: 27-32 (1989).
15. J. Diamond. "Overview: Laboratory experiments, field experiments, and natural experiments." In: J. Diamond and T.J. Case, eds. Community Ecology. Harper and Row: New York. pp. 3-22 (1986).
16. T.T. Kozlowski, H.A. Constantinidou. "Environmental pollution and tree growth. Part II. Factors affecting responses to pollution and alleviation of pollutant effects. Forestry Abstracts 47: 105-132 (1986).

17. J. Clausen, D.D. Keck, W.M. Hiesey. Experimental Studies on the Nature of Species. III. Responses of Climatic Races of *Achillea*. Carnegie Institute Publication Number 242. pp. 1-512 (1948).

18. A.E. Squillace, R.R. Silen. "Racial variation in Ponderosa pine." Forest Science Monographs 2:1-27 (1962).

19. J. Cairns. "The myth of the most sensitive species." Bioscience 36:670-672 (1986).

20. A. Brennan. Thinking About Nature. The University of Georgia Press: Athens, GA. pp. xiii+235 (1988).